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Developing Physics Teaching Materials with the SETS Approach on the Kinetic Theory of Gases Topic to Improve Students' Scientific Literacy Skills

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Abstract

Scientific literacy as a skill and competence must be possessed in physics learning. However, the ability to be literate has not been well-trained and has received insufficient attention in schools. This research aims to develop teaching materials that are valid, practical, and effective with the SETS approach to enhance the scientific literacy of students. This research uses the ADDIE model as a guideline in developing teaching materials. The research method used is a pre-experimental research trial with 36 students in the 11th grade of Science 2 class at SMAN 11 Banjarmasin. The results of the study show: (1) Physics teaching materials with the SETS approach are considered valid because the worksheets, lesson plans, and teaching materials, as well as the learning outcomes test, are categorized as very good; (2) Physics teaching materials with the SETS approach are considered practical because the implementation of teaching and learning activities is categorized as very good; (3) Physics teaching materials with the SETS approach are declared effective because the N-gain score for scientific literacy is 0.75 in the high category. Thus, physics teaching materials with the SETS approach to the kinetic theory of gases are considered suitable for use in teaching and learning activities to enhance students' scientific literacy because they meet the criteria of validity, practicality, and effectiveness. The results of this research are used as input for teachers and prospective teachers to choose physics teaching materials with the SETS approach on the topic of the kinetic theory of gases to enhance students' scientific literacy.

Keywords: Kinetic theory of gases; Scientific literacy; SETS; Teaching materials

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INTRODUCTION

The development of science and technology in the 21st century has driven the need for adaptation and self-improvement in the face of social changes (Pertiwi et al., 2018). Providing quality science education is a significant demand and challenge for teachers in delivering education in the 21st century (Aswita et al., 2022; Irsan, 2021; Muzijah et al., 2020). A socially literate environment in science is one where individuals can explain scientific facts and the relationships between science,

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society, and technology and can apply that knowledge to solving everyday problems (Fautin et al., 2020). Scientific literacy recognizes the importance of understanding and performing scientific thinking in addressing social challenges (Pratiwi et al., 2019). Therefore, it is essential to measure students' scientific literacy to assess the extent of their scientific literacy to achieve a high level of scientific literacy (Fuadi et al., 2020; Handayani & Istiyono, 2018). Scientific literacy is an individual skill involving issues and concepts related to science as reflective members of society, including the ability to apply scientific knowledge in real-life situations, plan and evaluate scientific research, interpret data scientifically, and explain phenomena using a scientific approach (OECD, 2018). Based on the results of the Programme for International Student Assessment (PISA) survey, the level of scientific literacy among Indonesian students is still low. In the 2018 science literacy survey, PISA ranked Indonesia 70th out of 78 countries with a score of 396 (Schleicher, 2019). Indonesia ranked bottom in PISA science literacy results, indicating the low quality of science education compared to OECD member countries. Students' lack of scientific literacy is due to factors including a teacher-centered approach to science learning, students' negative attitudes toward science learning, and their lack of interest in competencies related to science content, processes, and contexts (Fuadi et al., 2020; Irwan et al., 2019). Low scientific literacy makes students unresponsive to developments and issues in their surroundings, especially those related to natural phenomena, local advantages, and environmental issues (Pratiwi et al., 2019).

Based on the preliminary research results in class XI Science 2 at SMAN 11 Banjarmasin, it is evident that students still have low scientific literacy skills: 92.78% of students cannot explain phenomena using a scientific approach, 79.60% cannot design and evaluate scientific research, and 56.67% cannot interpret data and evidence scientifically. Based on the interviews with physics teachers at SMAN 11 Banjarmasin, physics education has not been effective in improving scientific literacy due to a lack of teaching materials related to the community environment. Therefore, an innovative learning process is needed to improve students' scientific literacy.

One effort to address this issue is the development of teaching materials that integrate Science, Environment, Technology, and Society (SETS) to cultivate scientific literacy skills among students. Integrated SETS learning has advantages in training students in problem-solving, innovation, independence, logical thinking, and a holistic perspective. It is also crucial to ensure close connections between science, technology, environment, and society in today's education reality (Prasojo et al., 2020; Sarjono, 2020). SETS is a forward-looking approach that connects science, the environment, technology, and society, enabling students to solve technical problems and understand their impact on the community and the environment (Hardianti et al., 2021). The implications of the research on developing physics teaching materials using the SETS approach are that students will be engaged in a learning process that allows them to develop scientific literacy skills. This includes applying physics concepts in the context of the kinetic theory of gases, adopting critical scientific attitudes, and using scientific thinking processes to analyze gas phenomena. Through teaching materials developed with the SETS approach, students will be able to expand their understanding of the kinetic theory of gases and enhance their overall scientific literacy skills (Widiastuti & Purnawijaya, 2021).

This is supported by a previous research study conducted by Hardianti et al. (2021) showing that SETS-based teaching materials can improve scientific literacy skills on the topic of living things' motion, as evidenced by positive student responses to successful SETS-based materials and significant test scores (0.009, < 0.05) across subjects. Another study by Sarjono (2020) using a scientific-based SETS learning model successfully improved student learning outcomes and activities. There was a significant increase in student mastery, from 46.88% to 87.50% in cycles I and II.

The researchers have analyzed students' competencies and characteristics and teaching materials in the context of the SETS approach to enhance students' scientific literacy skills, particularly in the kinetic theory of gases in physics. The kinetic theory of gases was chosen because it is abstract and requires an understanding of formulating equations, making it difficult to experiment with in the classroom. Active learning with a SETS-inspired approach is needed to enhance students' scientific literacy and help them understand challenging physics concepts. This approach brings students closer to various scientific phenomena in life, technology, and their impact on the environment and society, aligning with the scientific literacy competencies defined by the OECD (2018).

In general, this research aims to describe developing teaching materials that meet the criteria. Specifically, the research aims to: 1) describe the validity of the developed physics teaching materials, 2) describe the practicality of the developed physics teaching materials, and 3) describe the effectiveness of the developed physics teaching materials.

METHOD

This research employed the Research and Development (R&D) method to develop a new product and validate and test the practicality of the developed product (Setyosari, 2016). The instructional material development model follows the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The ADDIE model uses a systemic approach to design instructional systems. It essentially divides the learning planning process into several stages, organizes the steps in a logical sequence, and then uses the results from each step as input for the next step (Cahyadi, 2019). The research subjects are 36 students in the 11th grade of Science 2 class at SMA Negeri 11 Banjarmasin for the academic year 2022/2023. The selection of these research subjects was made because there was no prior research related to scientific literacy skills at the school, and it was based on the results of pre-observation of scientific literacy in the 11th-grade Science classes at SMAN 11 Banjarmasin. The results indicated that the students in the 11th-grade Science 2 class showed better scientific literacy skills than the other two classes. Therefore, the 11th-grade Science 2 class was chosen as the research subject because it had a strong foundation in scientific literacy. This is in line with the goal of this research to develop and improve students' scientific literacy skills without the need to retrain them in the basics of scientific literacy that they have already mastered. By developing appropriate teaching materials, it is expected that this research can significantly contribute to enhancing the students' scientific literacy skills in the 11th-grade Science 2 class. The research object is the suitability of the physics teaching materials with the SETS approach to improve students' scientific literacy skills.

The research method used was a single-group pre-experimental design, measuring once at the beginning (pretest) before the treatment and then measuring again at the end (posttest) (One Group Pretest-Posttest) based on the scheme established by Sugiyono (2019). The teaching materials were validated by three validators, one academician, and two physics teaching practitioners. Validity was obtained by calculating the total average score for assessment aspects based on the assessment criteria established by Widoyoko (2016), and reliability was determined according to Cronbach's Alpha by the criteria set by Arikunto (2015). Three observers evaluated the practicality of the teaching materials through the implementation of lesson plans. The trial was conducted using a scientific literacy test, and the data were analyzed by calculating the N-gain and strengthening the analysis results based on the assessment criteria by Hake (1998). The scientific literacy competencies analyzed were adapted to the assessment criteria according to Irwan et al. (2019), as shown in Table 1.

Table 1 The ability to master scientific literacy

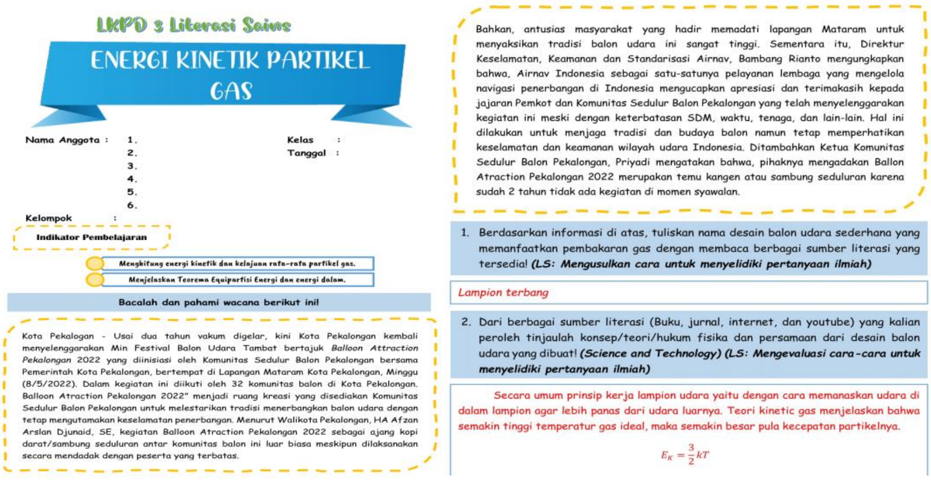
No	Scores	Category
1	$66.6 < x \leq 100.0$	High
2	$33.3 < x \leq 100.0$	Medium
3	$0.0 < x \leq 33.3$	Low

RESULTS AND DISCUSSION

The product developed is a physics teaching material with the SETS approach to the kinetic theory of gases. This teaching material is designed specifically to meet the learning needs that align with the characteristics of the students. The SETS-integrated learning content in this teaching material includes airbags in cars, scuba diving, aerosol cans (spray cans and inhalers), and hot air balloons, all aimed at enhancing scientific literacy skills acquired from various sources and their living environment. The advantage of developing teaching materials lies in their ability to enable students to use the material independently, characterized as self-instructional, meaning that the teaching material developed can promote self-directed learning by students (Hardianti et al., 2021). It includes issues or information about the kinetic theory of gases that have a close relationship between science and technology and their positive impacts on the environment and society, enabling students to conclude the advantages and disadvantages of technological advancements (Sarjono, 2020). Below is a display of the teaching material and worksheets (*Lembar Kinerja Peserta Didik* or LKPD) that have been developed.

(a) (b)

Figure 1 Display of SETS-based scientific literacy physics teaching material



(a) (b)

Figure 2 Display of SETS-based scientific literacy physics worksheets

Figure 1 shows the "Literacy Corner" with integrated SETS elements. In Figure 1(b), the teaching material introduces a new element, the "Literacy Corner," as an innovation in the developed media. This element represents innovation in the development of learning materials. In this concept, everyday physics problems are connected to relevant technology and their impacts on society. This "Literacy Corner" is the main differentiator from typical school teaching materials. Typically, reading corners focus only on events related to scientific concepts but rarely demonstrate connections to technology and social benefits. According to Maknun et al. (2018), applying the SETS vision to explore a scientific event allows students to connect scientific concepts with other elements of SETS. Through the adaptation of the SETS approach that aligns with student's interests and talents, it is expected that students will become more interested and motivated in the learning process. This approach can stimulate students' curiosity and support their initiative in understanding learning content more deeply (Parmin & Savitri, 2020). The inclusion of the "Literacy Corner" in teaching materials is an important step where students are expected to develop a deeper understanding of how science, technology, and social impacts are interconnected in the context of real life.

Figure 2 shows Integrated SETS and Scientific Literacy Student Worksheets. In Figure 2(a), a discourse about the event of flying a hot air balloon is presented, connecting scientific concepts with the average particle motion speed during hot air balloon flights and its impact on the community and the environment. In Figure 2(b), the questions in the student worksheets are matched with scientific literacy indicators and elements of SETS. The interconnection between each scientific literacy indicator and SETS elements in the student worksheet questions sets it apart from commonly used worksheets. Typically, a physics worksheet focuses only on discovering scientific concepts or solving scientific work-related problems. Research conducted by Atmojo & Kurniawati (2018) revealed that learning involving SETS principles can encourage students to understand concepts and improve scientific literacy skills. Students are not just observing phenomena around them but are also invited to design comprehensive ways to address environmental issues. The implementation of the student worksheet developed in this research involves students mastering fundamental scientific literacy indicators, such as formulating accurate hypotheses based on observations and available information, as well as training their ability to ask questions and design technology, environmental, and social aspects related to the problems being studied (Gathong & Chamrat, 2019). Thus, the learning conducted in this research aims not only to improve students' understanding of scientific concepts but also to train their ability to read, analyze, and critique information scientifically.

Validity Results of the Teaching Materials

The validity results of teaching materials aim to ensure the authenticity or suitability of teaching materials to support the teaching and learning process in the classroom. The validity results of the lesson plan have an average score of 3.75 in the excellent category and very high reliability at 0.86, meeting the standards for a good lesson plan component. In the direct learning model, students become accustomed to and experience positive changes in knowledge, attitudes, and skills, transforming them from unknowing to knowledgeable (Rainis, 2019). In problem-based learning, significant learning involves active student participation through problem-solving methods, the application of acquired knowledge, and efforts to acquire new relevant knowledge (Afiat, 2022; Prastika et al., 2019; Sulistiyo et al., 2021).

The validity results of teaching materials have an average score of 3.77 in the excellent category and very high reliability at 0.81. This was obtained by assessing criteria within the teaching material validation sheets. Assessment aspects include usefulness, presentation content, language, and format. The development of teaching materials in this research incorporates scientific literacy indicators through teaching materials combined with the SETS approach; enhancing scientific literacy involves understanding not only the structure of science and technology but also their nature and their relationship with the environment and society through direct experiences to strengthen students' understanding (Hardianti et al., 2021; Widiastuti & Purnawijaya, 2021).

The validity results of worksheets have an average score of 3.61 in the excellent category and very high reliability at 0.83. This was obtained from assessing criteria within the aspects of the student worksheet validation sheets. Assessment aspects include format, language, and the student worksheets content. The student worksheets in learning motivates students to address issues relevant to their lives actively, increases student satisfaction with learning, and develops their independence in the learning process (Kasumawati, 2021).

The validity results of the scientific literacy test have an average score of 3.73 in the excellent category and very high reliability at 0.81. This was obtained from assessing criteria within the aspects of test validation sheets. Assessment aspects include topics, general construction, scientific literacy, and item validity. The test of scientific literacy developed in this research is also used as a test of scientific literacy to assess the effectiveness of the physics teaching materials developed by the researcher. Each question created refers to indicators of learning about the theory of kinetic gas and includes one scientific literacy indicator. Although the test of scientific literacy developed already met the criteria for excellence, the validator suggested some improvements before using the scientific literacy test. Improvements made included adding a reason column in multiple-choice questions, adjusting scoring guidelines according to the cognitive level of the questions, and in essay questions, improving the value known in the question with an application example found in the discourse. Adding reasons in multiple-choice questions was one of the improvements suggested by the validator. Research (Istiyono et al., 2018) states that in multiple-choice tests, two factors contribute to the difficulty level, which are the presence of confusing choices (distractors) and the opportunity for respondents to guess the answers. In line with this, (Samaduri, 2022) states that multiple-choice instruments expanded with a multi-response format were developed to measure critical thinking skills and students' understanding. They must provide reasons behind their answer choices, making the assessment more similar to an essay test. Furthermore, research (Odden et al., 2019) states that the purpose of this instrument is to evaluate students' holistic abilities in learning physics, allowing them to think deeply and explain their answer choices, providing a comprehensive picture of students' understanding related to scientific literacy in physics learning, where they are capable of applying physics concepts in real-life contexts, adopting critical scientific attitudes, and using scientific thinking processes.

Practicality of the Teaching Materials

The practicality of physics teaching materials using the SETS approach on the topic of kinetic gas theory in this research was assessed based on the implementation of the lesson plan conducted three times. Overall, the implementation of the lesson plan is categorized as excellent, with high reliability in each learning phase. This indicates that the learning steps and scenarios, as well as other learning materials like the student worksheet and teaching materials within the lesson plan, are highly feasible to be carried out.

The instructional model in the lesson plan uses both direct instruction and problem-based learning. In the first and second meetings, direct instruction is employed. In line with the opinions of Izzati et al. (2020) and Rainis (2019), student characteristics influence the selection of instructional models. If students' characteristics involve relatively simple thinking levels, then direct instruction can be used. Subsequently, as students become accustomed to direct instruction during classroom learning, the instructional model is upgraded to problem-based learning. This model was chosen because students have undergone learning stages that facilitate the development of their problem-solving abilities, group-based opinion formulation, and determining what they have learned to address issues through critical thinking (Aini et al., 2022).

Effectiveness of Teaching Materials

The effectiveness of teaching materials in this research is assessed based on the N-gain scores of students' test results (scientific literacy test). The test was conducted before (pretest) the use of physics teaching materials and after (posttest) the use of physics teaching materials. The analysis of test results (test of scientific literacy) is calculated based on several scientific literacy indicators. Then an N-gain test is performed to determine the improvement before and after the treatment. The results of the N-gain calculations can be seen in Table 2.

Table 2 Results of N-gain calculations for students' learning test results

Average of *Pretest*	**Average of *Posttest***	***N-gain* <g>**	**Category**
19.25	79.44	0.75	High

The ability of scientific literacy can be evaluated through students' responses in the learning test with scientific literacy indicators. Based on the assessment of the test, the average achievement of each scientific literacy indicator is shown in Figure 3.

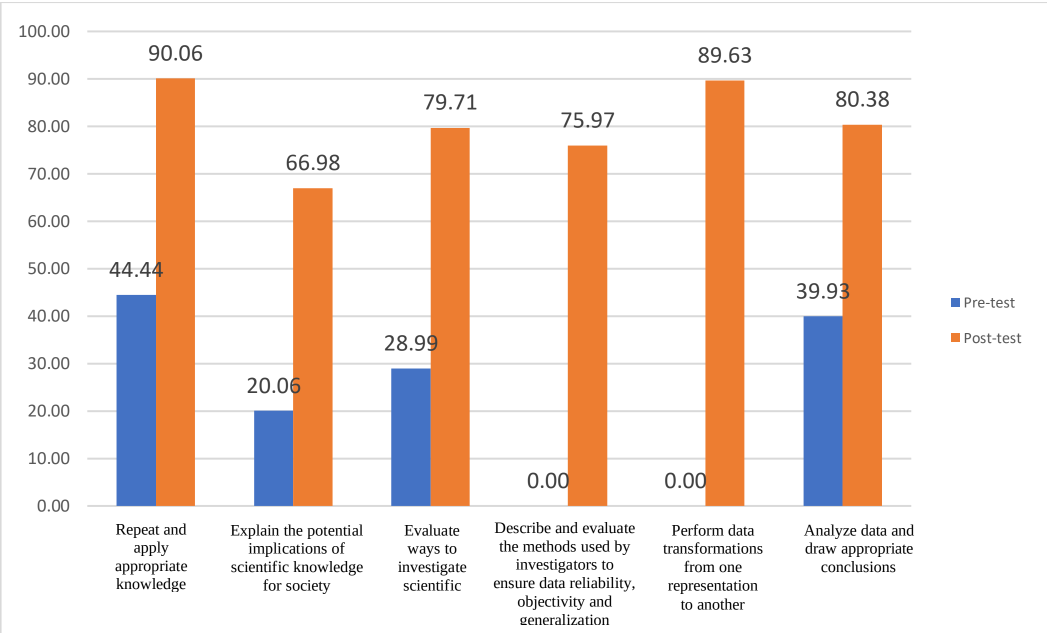


Figure 3 Achievement of scientific literacy indicators for students

The results presented in Figure 3 illustrate the achievements and categories of each scientific literacy indicator before and after the implementation of physics teaching materials with the SETS approach in the learning activities. The test of scientific literacy or Scientific Literacy Test is a cognitive test consisting of reasoned multiple-choice and essay questions, totaling six items in the C2-C5 domains. Table 2 shows an increase in students' average scores after the research was conducted. The learning process resulted in positive changes in student behavior through the gradual construction of knowledge, as seen through the increase in average scores in the posttest (Rainis, 2019). The N-gain score obtained, as shown in Table 2, is categorized as high. This means that the development of teaching materials has effectively improved students' learning outcomes.

Each question in the learning test covers scientific literacy skills. Based on Figure 3, in the pretest, all students scored low in each scientific literacy indicator. This result was obtained from 36 students, 7 in the moderate category and 29 in the low category before the learning process. This result is consistent with the initial study conducted by the researcher in class XI MIPA 2 at SMAN 11 Banjarmasin. As shown in Figure 3, 4 indicators were in the low category, and only two were in the moderate category. Some indicators were not achieved due to the lack of learning resources that can train students' scientific literacy skills. They are rarely presented with teaching that connects environmental issues through literacy activities from various sources, resulting in lower problem-solving skills, slower understanding of physics materials, and minimal scientific literacy (Andriani et al., 2018). This result aligns with previous research, indicating that integrating science, social environment, and technology elements in learning materials has a very low percentage. Additionally, school science learning tends to focus on the product aspect, neglecting the process and attitude aspects. This leads to lower student abilities in building scientific literacy, negatively impacting their understanding of concepts and declining learning outcomes (Handayani & Istiyono, 2018).

The average posttest scores show that students' scientific literacy indicators increased after implementing physics teaching materials with the SETS approach. This indicates the success of developing teaching materials in improving students' scientific literacy from the pretest to the posttest. The achievement of increased scientific literacy indicators also shows that six indicators are in the high category in the posttest results. The highest posttest score is in the scientific literacy indicator of recalling and applying relevant knowledge. This is because most students could already explain the role of nitrogen gas in airbags in providing driver safety in the event of an accident. The same question had been practiced in the student worksheet 1, indicating that students paid close attention to the learning, allowing them to recall their knowledge effectively. The scientific literacy indicator of analyzing data and describing appropriate conclusions also achieved the highest posttest score. This is because the questions used were at a lower level compared to other scientific literacy indicators.

The lowest posttest score in scientific literacy was obtained in the indicator of elaborating possible implications related to scientific knowledge for society. This is because some students still did not understand the concept in the question, which involved analyzing the negative impact of flying a hot air balloon and providing alternative solutions. The same question had been practiced in the student worksheet 3, but some students were confused by other answer choices. This indicates that the question was challenging, making it difficult for students to focus on analyzing the negative impact of flying a hot air balloon and explaining the appropriate alternative solution. The scientific literacy indicator of evaluating ways to investigate scientific questions also significantly improved. Students were asked to determine which windmill would spin the fastest among three scenarios. Most students understood the correct answer but could not explain the reasoning accurately. The cognitive domains of these questions were C4 and C5, which are high-order thinking skills (HOTS), as seen in the difficulty students faced in problem-solving. This result is consistent with previous research findings, indicating that students tend to focus more on the mathematical aspect of learning, leading them to search for formulas to solve problems rather than analyzing with their existing knowledge.

The average score increased from low to high in the scientific literacy indicator of transforming data from one representation to another. In the initial ability test, none of the students could answer the question or even mention what was known in the question. Students were asked to determine the gas pressure in a pump tire tube. However, after practicing the same question in the student worksheet 1, the results showed that students could determine the gas pressure in a closed space using the ideal gas equation.

The same improvement was seen in the scientific literacy indicator of describing and evaluating the methods used by researchers to ensure data reliability, objectivity, and generalizability. In the initial ability test, none of the students could answer the question or even mention what was known in the question. Students were asked to determine which gas molecule would move faster if a tube contained helium and nitrogen gases mixed in a closed space. However, some students still had difficulty understanding the concept in the question. This was due to the complexity of the question, making it challenging for students to analyze the negative impacts of flying a hot air balloon and provide the correct alternative solution.

Overall, the scientific literacy test results showed an N-gain score of 0.75, which falls into the high category. This indicates that more than half of the students achieved the school's minimum passing grade of 73, thus meeting the minimum criteria for developing teaching materials. Implementing physics teaching materials with the SETS approach has effectively improved students' abilities in each scientific literacy indicator. According to Hidayati et al. (2018) and Sulistiyo et al. (2021), learning becomes more engaging for students because the facts used in the learning process connect to the knowledge and experiences that students have, contributing significantly. Through the integrated SETS learning approach, it is hoped that students can broaden their understanding of scientific knowledge, its development, and how the progress of science can mutually influence the environment, technology, and society (Nurcahyani et al., 2021).

Several previous studies have found that using teaching materials integrated with the SETS approach can improve students' ability to apply scientific concepts and relate them to everyday life.

They also realize that science, social environments, and technology are interconnected and mutually influential. Students have achieved a multidimensional understanding of science that helps them develop their scientific literacy skills (Hardianti et al., 2021). According to Ummah et al. (2018), learning with the SETS approach to enhance scientific literacy is built on the Constructivism learning theory, where students are guided to connect the elements of SETS. The learning process begins by identifying examples that students recognize in their environment, and through this understanding, they can construct new knowledge (Sarjono, 2020).

Consistent with Hake's (1998) opinion, the effectiveness of learning using the development of teaching materials can be determined by the level of success or achievement in using the developed teaching materials, measured using N-gain scores. Improvement in students' scientific literacy test results is obtained from each meeting, as students are guided to solve problems that require contextual problem-solving and mastery of students' literacy and numeracy skills. In addition to improving learning outcomes, scientific literacy makes learning more meaningful. Scientific literacy skills play a crucial role in meaningful learning because, through strong scientific literacy skills, students can apply scientific concepts relevantly in everyday life, adopt a critical scientific attitude in analyzing information, and use scientific thinking processes through investigation and problem-solving to gain a deeper understanding of natural phenomena and the world around them (Medová et al., 2022).

The results of developing this physics teaching material also reveal several weaknesses that need to be addressed. First, students have a relatively low ability to explain the potential implications of scientific knowledge for society. This indicates the need to enhance their understanding of the relevance and application of science in everyday life. Second, teacher guidance in completing the Student Worksheets is still dominant because students are not yet accustomed to Scientific Literacy. This suggests more room for students to develop critical thinking, independence, and literacy skills in the learning process. Third, the average posttest scores have not been fully optimal because some students are still below the Minimum Mastery Criteria, so overall classical mastery has not been achieved. Therefore, additional efforts are needed to provide deeper support for understanding the material and improving students' learning abilities to achieve more satisfactory results. By identifying and addressing these weaknesses, learning development can continue to improve to achieve better results and effective student learning.

CONCLUSION

Based on the try-out, it is evident that students' scientific literacy skills have improved from before and after using integrated physics teaching materials with the SETS approach. From these results, it can be concluded that the developed teaching materials are suitable for use in teaching and learning activities to enhance students' scientific literacy in kinetic gas theory. This research also found that many students were misled by incorrect answer choices in scientific literacy indicators, indicating a lack of understanding of concepts. In future research, it is hoped that there will be better development in addressing students' misconceptions in scientific literacy test questions.

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